

THE LOFAR INTERNATIONAL TELESCOPE - ITALIAN INVOLVEMENT -

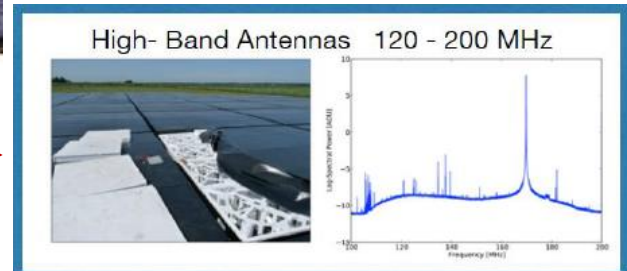
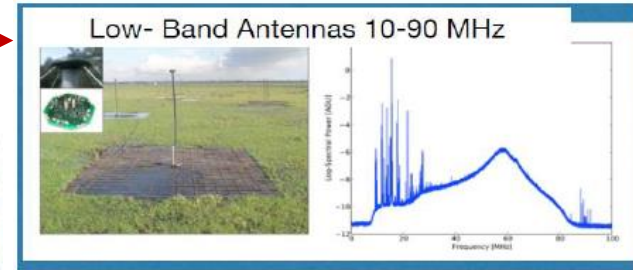
Gianfranco Brunetti



THE LOW FREQUENCY ARray

Giant digital aperture array radio telescope opening up a new window in the electromagnetic spectrum at low radio frequencies

(van Haarlem + 2013)



9 Countries
24+14+14(15) stations

THE LOW FREQUENCY ARray

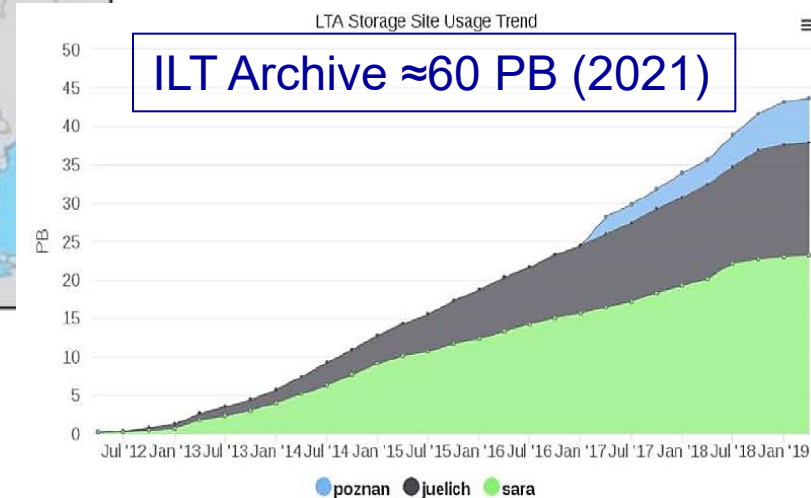
Giant digital aperture array radio telescope opening up a new window in the electromagnetic spectrum at low radio frequencies
- The largest (area & dataflow) pathfinder toward the SKA(low) -

(van Haarlem + 2013)

- ✓ 250 Gb/s across the entire network
- ✓ Large FoV, n baselines, n channels, produce typical **TB-size datasets**
- ✓ Archiving problem and managing Big Data



9 Countries
24+14+14(15) stations



OGGI LA FIRMA NEI PAESI BASSI

L'Italia fa ancor più grande Lofar

Il radiotelescopio europeo si estende anche all'Italia, con il contratto per la realizzazione di una nuova stazione presso Medicina, in provincia di Bologna. Nichi D'Amico: «L'adesione dell'Italia rappresenta un passo importante per Inaf»

Ufficio stampa Inaf 16/04/2018

Tweet



LOFAR upgrade... LOFAR 2.0

CONDITIONS :

- Technological task (400 kE)
- Annual ILT fee (90 kE/yr)
- Signed Contract for LOFAR 2.0 Station (1.5 ME, 2023)

BENEFITS :

- National voting member in ILT BOARD
- Reserved access (66 hrs/yr for 2018-24) for short programs
- Involvement in Science KPs (balance of Member return-on-investment/interests)
- 10% use of the Station in Local mode (2023++)

ASTRON

TELESCOPES ASTRONOMY RESEARCH & INNOVATION NEWS & EVENTS EDUCATION ABOUT OVERVIEW

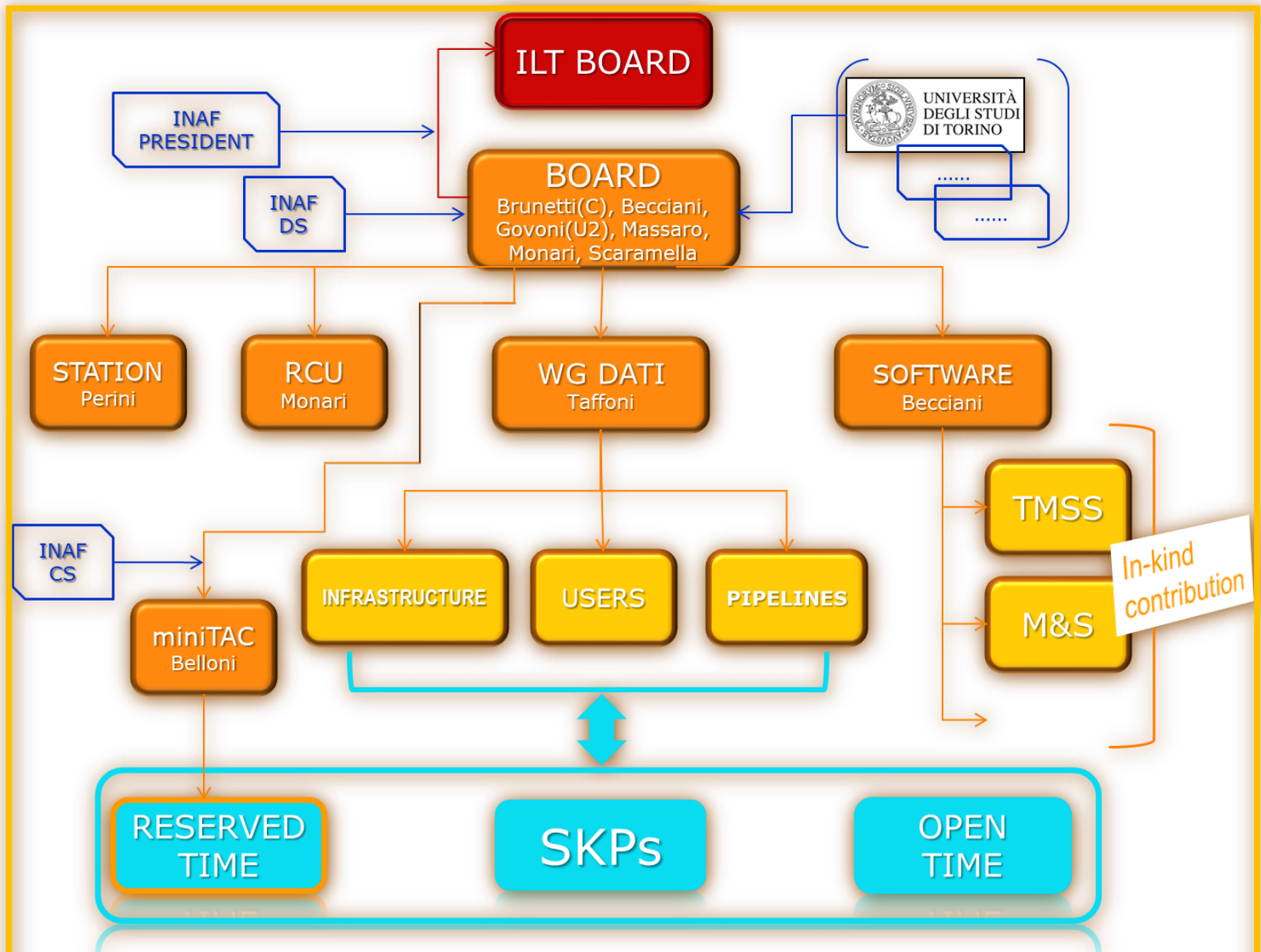


LOFAR crosses the Alps; Italy joins

NEWS — Today, 16 April 2018, Italy officially became a member of the International LOFAR Telescope (ILT). A contract has been signed by the Netherlands Institute for Radio Astronomy (ASTRON) and the Italian National Institute for Astrophysics (INAF) for a Low Frequency Array (LOFAR) antenna station. It will be installed at the Medicina Radio Observatory site, 30 kilometres from Bologna, Italy.

PUBLISHED BY THE EDITORIAL TEAM, 16 APRIL 2018

LOFAR-It: Management & Organization





UNIVERSITÀ
DEGLI STUDI
DI TORINO

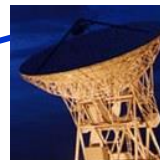


OATo

OATs



IRA



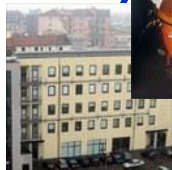
OAS



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA
DIPARTIMENTO DI FISICA E ASTRONOMIA

IASF-Mi

BRERA



OAA



OACa



IAPS-Rm



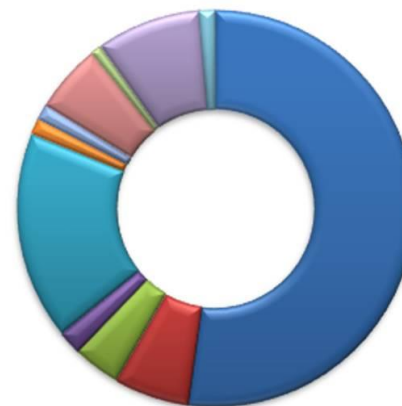
OA-Rm

OACt



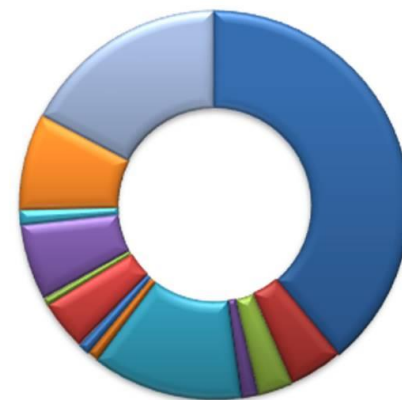
~32 FTE (~80 people)

INAF (TI+TD+E)



- IRA
- IASF-Mi
- IAPS-Rm
- OARm
- OACT
- OATo
- OACa
- OATs
- OAPd
- OAA
- OAS

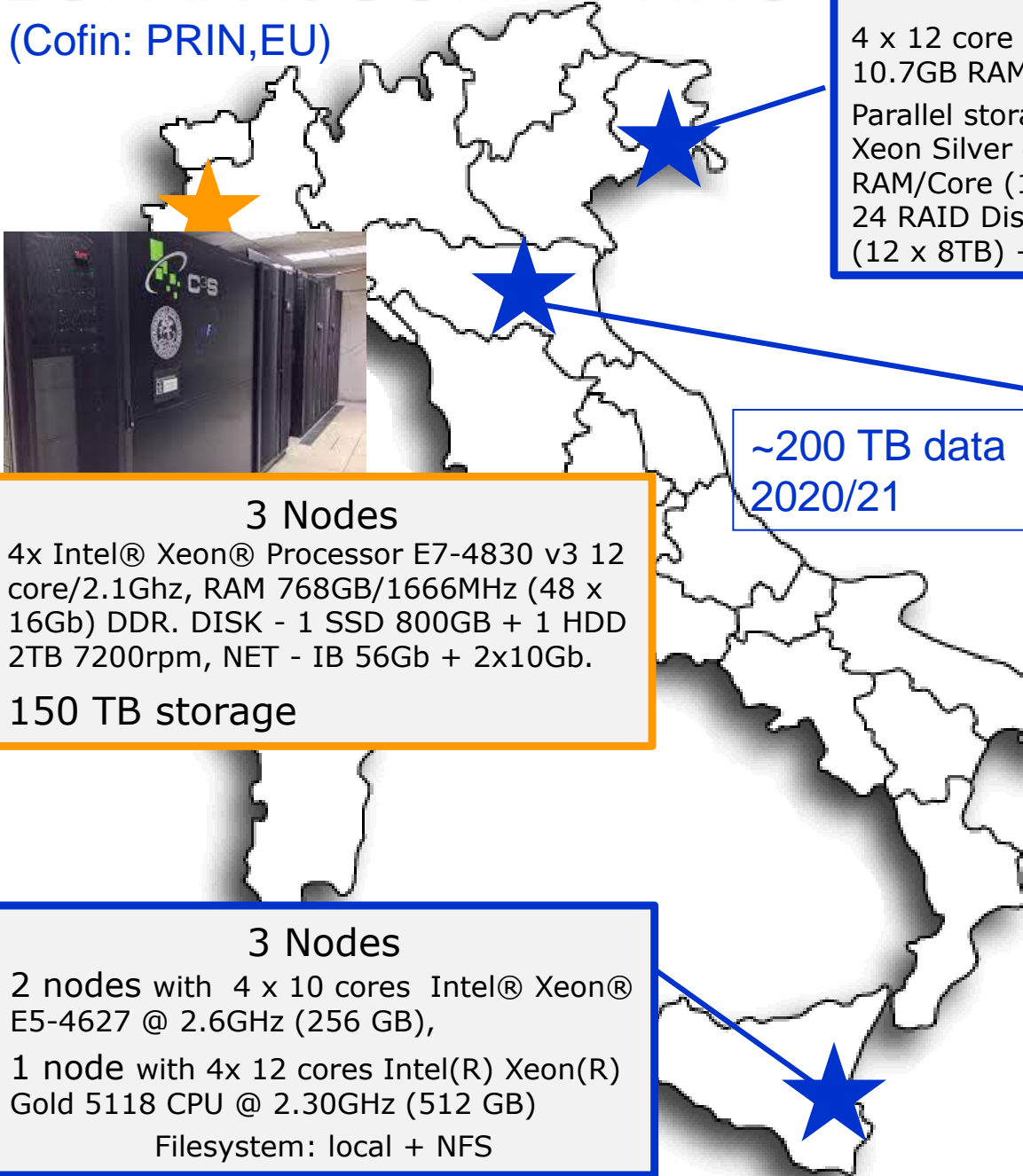
TOT (TI+TD+E)



- IRA
- IASF-Mi
- IAPS-Rm
- OARm
- OACT
- OATo
- OACa
- OATs
- OAPd
- OAA
- OAS
- UniTo
- UniBo

LOFAR-It COMPUTING

(Cofin: PRIN,EU)



4 Nodes
 4 x 12 core Intel Xeon Gold 5118 @ 2.30GHz
 10.7GB RAM/Core (512 RAM)
 Parallel storage BeeGFS: 4 Nodes IO : 16 Intel Xeon Silver 4110 CPU @ 2.10GHz 8 GB RAM/Core (128 RAM)
 24 RAID Disks on 1883IX Areca RAID 2 raid6 (12 x 8TB) + (12 x 4TB)

3 Nodes
 4x Intel® Xeon® Processor E7-4830 v3 12 core/2.1Ghz, RAM 768GB/1666MHz (48 x 16Gb) DDR. DISK - 1 SSD 800GB + 1 HDD 2TB 7200rpm, NET - IB 56Gb + 2x10Gb.
 150 TB storage

~200 TB data
 2020/21

IRA: 8 Nodes, 300 TB storage

Name	RAM	CPU	Cores	Clock	Data Net	Work Disk (DAS HD)	Scratch Disk (DAS SSD)	GPU	schedul
lofar1	512G	Intel Xeon E5-2640 v4	2 x 10/20	2400/3400	1GbE	28TB (4x6TB)	196GB	N	
lofar2	384G	Intel Xeon Gold 6130	2 x 16/32	2100/3700	10GbE	19TB (2x10TB)	65GB	N	
lofar3	384G	Intel Xeon Gold 6130	2 x 16/32	2100/3700	10GbE	10TB (1x10TB)	65GB	N	
lofar4	384G	Intel Xeon Gold 6130	2 x 16/32	2100/3700	10GbE	19TB (2x10TB)	65GB	N	
lofar5	384G	Intel Xeon Gold 6130	2 x 16/32	2100/3700	10GbE	19TB (2x10TB)	65GB	N	
lofar6	384G	AMD EPYC 7401	2 x 24/48	2000/3000	10GbE	19TB (2x10TB)	65GB	N	
lofar7	512G	AMD EPYC 7452	2 x 32/64	2350/3350	10GbE	33TB (4x10TB)	169GB	RTX 2080 Ti	N
lofar8	512G	AMD EPYC 7452	2 x 32/64	2350/3350	10GbE	33TB (4x10TB)	169GB	RTX 2080 Ti	N

Storage [edit](#)

Name	RAM	CPU
lofarnas0	32G	Intel Xeon Silver 4110




3 Nodes
 2 nodes with 4 x 10 cores Intel® Xeon® E5-4627 @ 2.6GHz (256 GB),
 1 node with 4x 12 cores Intel(R) Xeon(R) Gold 5118 CPU @ 2.30GHz (512 GB)
 Filesystem: local + NFS

Cofund
 DRANOEL



SOFTWARE & TECHNOLOGY

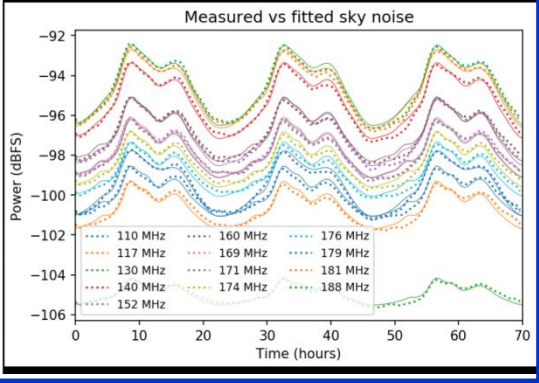
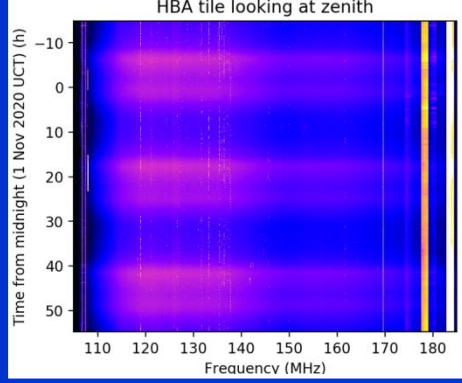
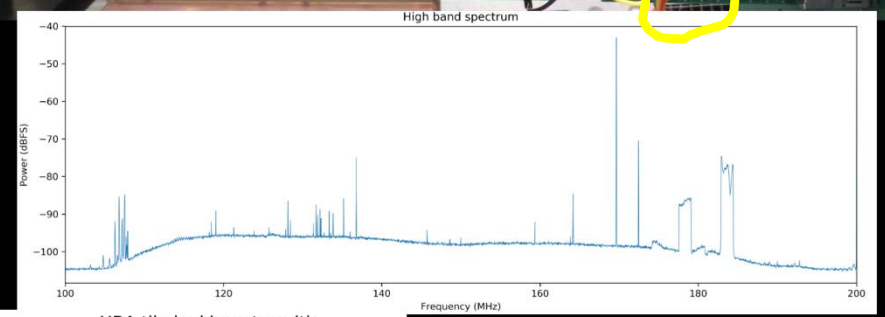
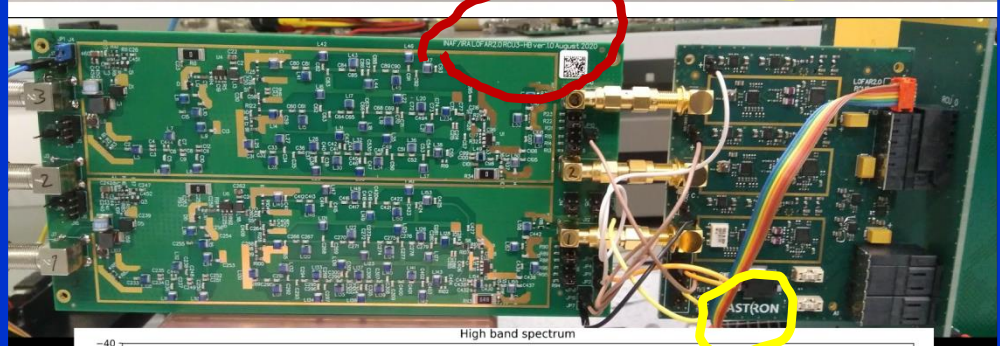
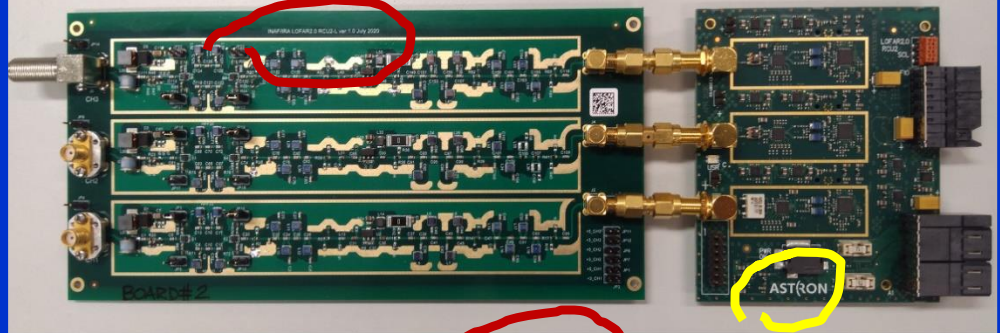
- ❑ Telescope Manager Specification System (TMSS)
- ❑ Monitor and Control (M&C) Subsystem for LOFAR 2 Station
- ❑

❑ RCU  IT is the only other country to contribute to LOFAR tech besides NL

- ❑ STATION (2021+)
 - INTERFERENCES (2021)
 - POWER (2021+)
 - TERRAIN (2022+)
 - ROLLOUT (2023)
 - TESTING + CALIBRATION (2023)
 - MAINTAINANCE (2023+)



RCU LBA+HBA INAF & ASTRON

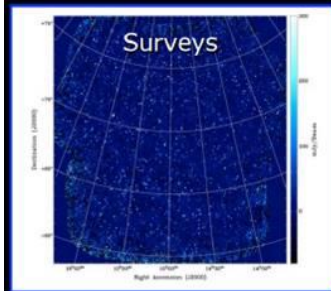


INVOLVEMENT IN KPs : priority task

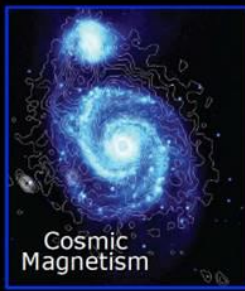
LOFAR KEY SCIENCE PROJECTS

The most impactful scientific activity and technical solutions are developed within these communities

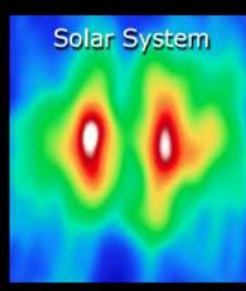
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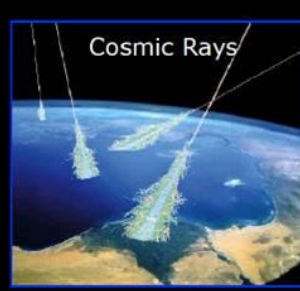
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5



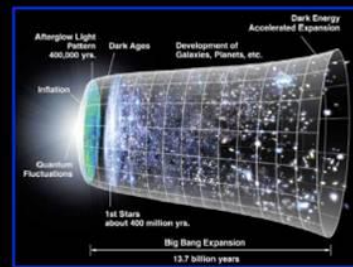
6



3



2



TI MEMBERS (32)



- SKP
- MKP
- TKP
- SOLAR

Involvement in Science KPs is based on balance of **Member return-on-investment**

- IT investment is (only) about 1/50 of the ILT.
- IT science community is much bigger/active than several other communities from Member countries with larger investment
- IT science community has potential to activate synergies with other large facilities

INVOLVEMENT IN KPs : priority task

LOFAR KEY SCIENCE PROJECTS

The most impactful scientific activity and technical solutions are developed within these communities

1

4

5

6

Surveys

Cosmic Magnetism

Solar System

Cosmic Rays

3

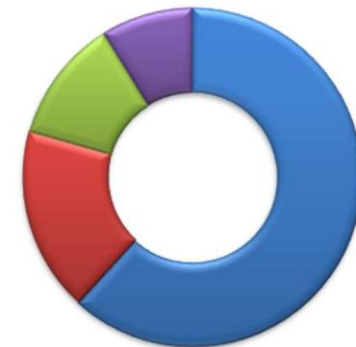
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Transient sky

Pulsars

Epoch of Reionization

TI MEMBERS (32)



SKP

MKP

TKP

SOLAR

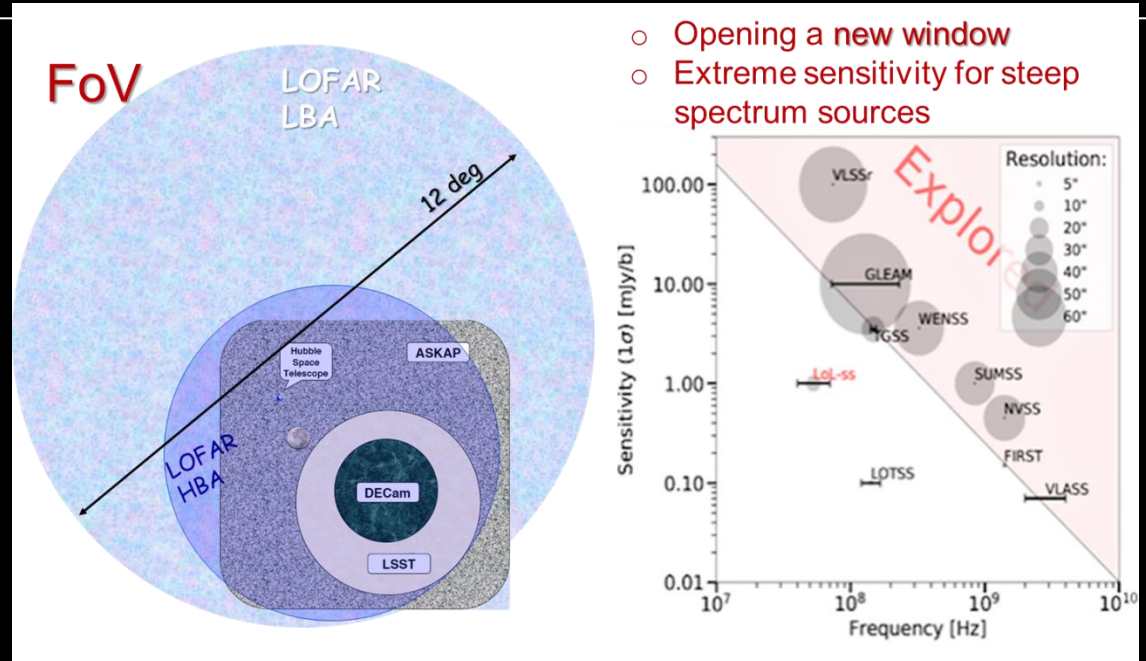
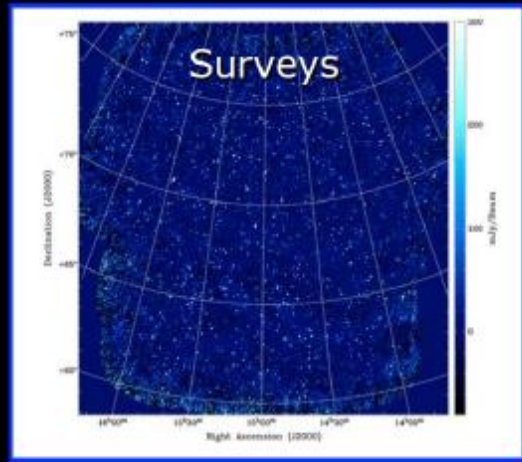
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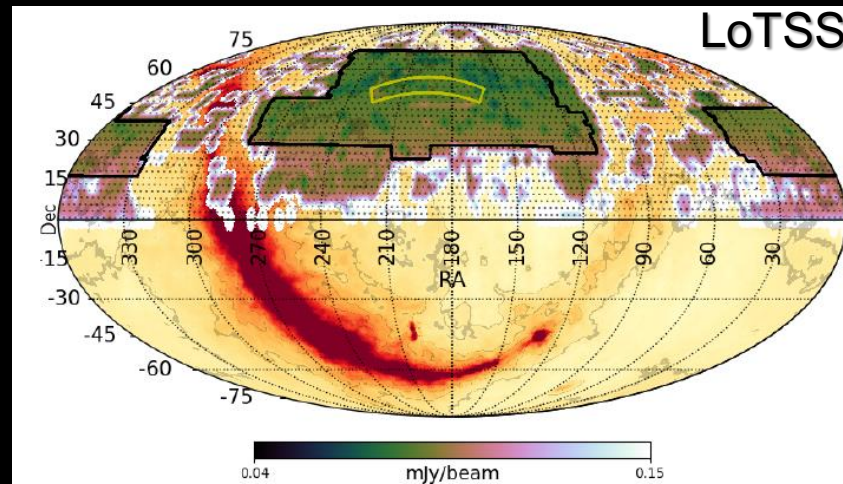
LOFAR KEY SCIENCE PROJECTS

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1



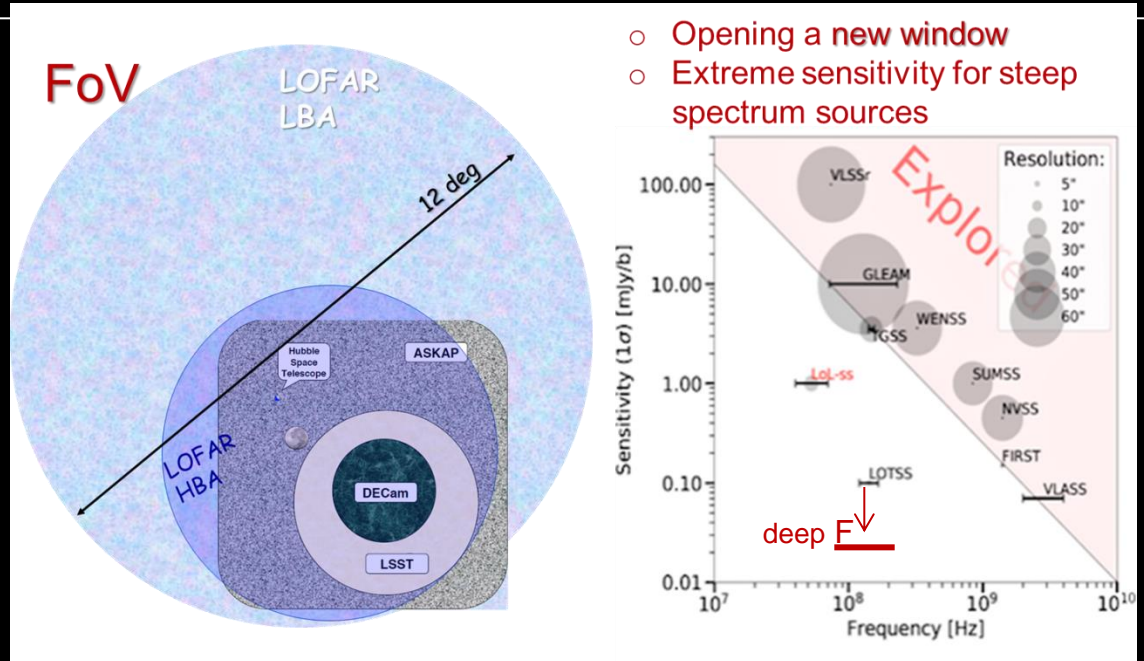
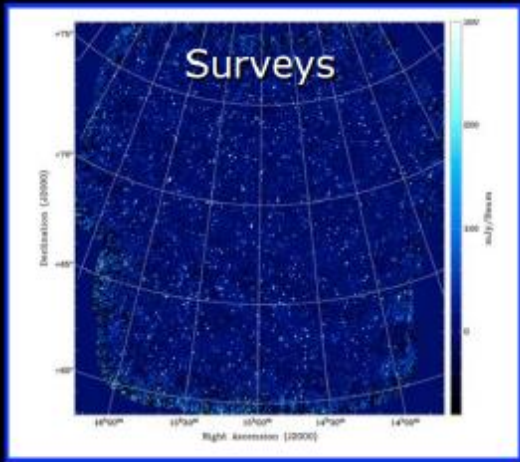
(Shimwell+ 17,19, 21 de Gasperin+ 21)



LOFAR KEY SCIENCE PROJECTS

The most impactful scientific activity and technical solutions are developed within these communities

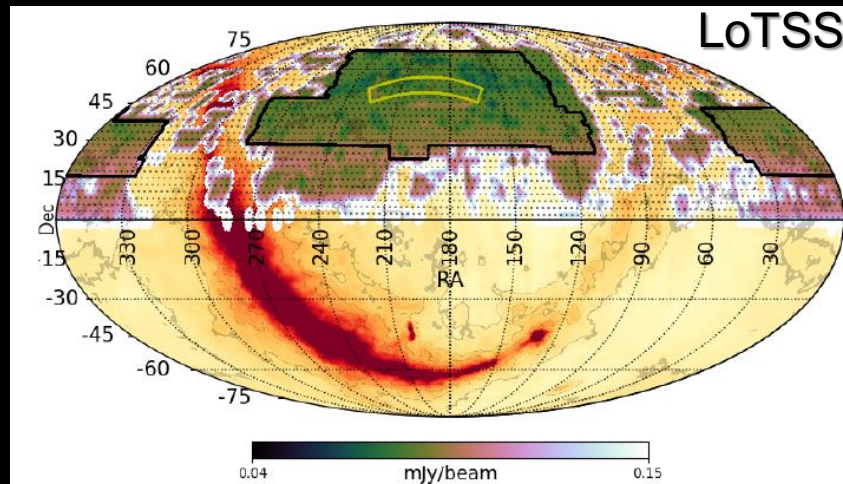
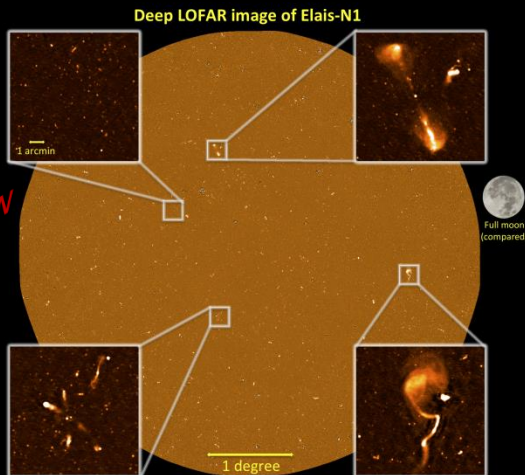
1



- Opening a new window
- Extreme sensitivity for steep spectrum sources

LOFAR deep Fields

(Shimwell+ 17,19, 21 de Gasperin+ 21)



LEADERSHIP & IMPACT ON IT SCIENCE

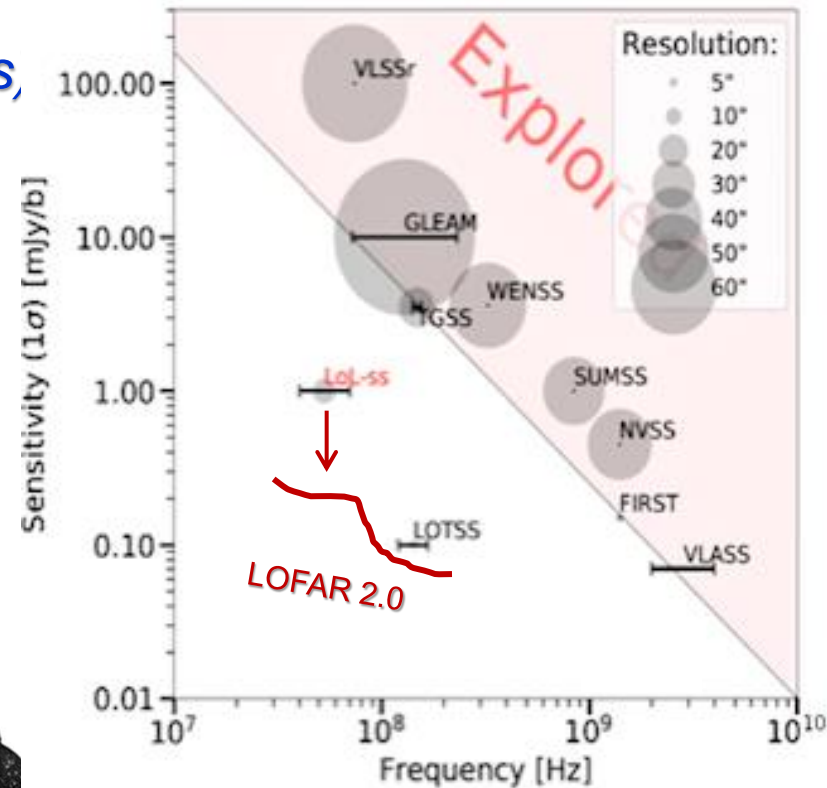
SurveyKP : *over-represented (21 TI members)*

- 2 members in the KP Board
- Involved in many SWG, **leading 2/12 SWG** (galaxy clusters, LBA)
- Piship of LoLSS (1/2 Tier 1 surveys)
- Synergies :
 - WEAVE-LOFAR
 - eROSITA
 - EUCLID: Piship of EDFN (1/4 deep fields)

LEADERSHIP & IMPACT ON IT SCIENCE

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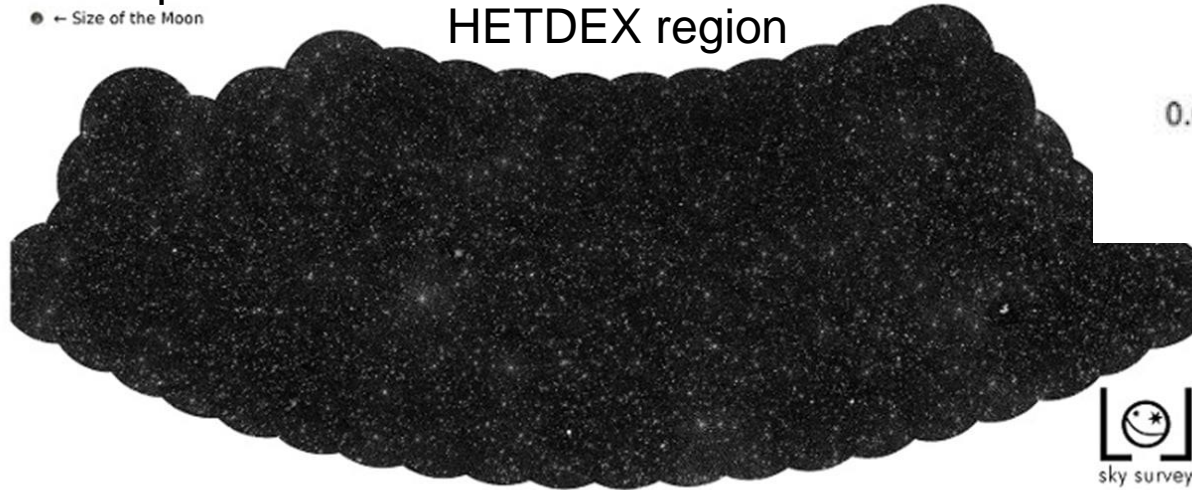
- 2 members in the KP Board
- Leading 2/12 SWG (galaxy clusters, LBA)
- **PIship of LoLSS (1/2 Tier 1 surveys)**
- Synergies :



de Gasperin+ 2021

HETDEX region

• ← Size of the Moon



Additional **1400** observing hrs have been awarded in 2021-22



LOFAR 2.0 precursor !

Challenges

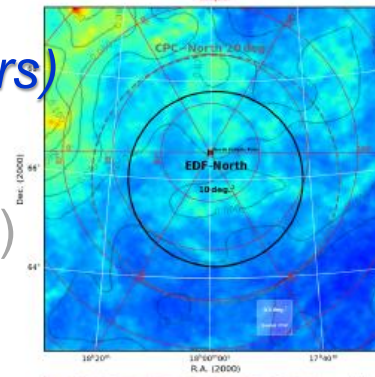
- computing/storage capacity
- Manpower/personnel

LEADERSHIP & IMPACT ON IT SCIENCE

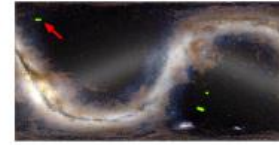
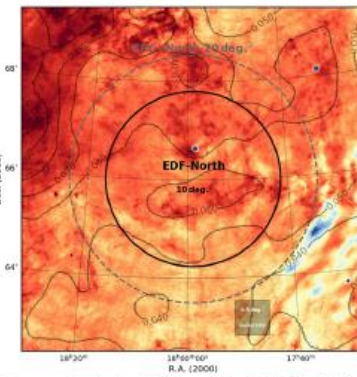
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Extinction: E(B-V)



Galactic cirrus patchiness



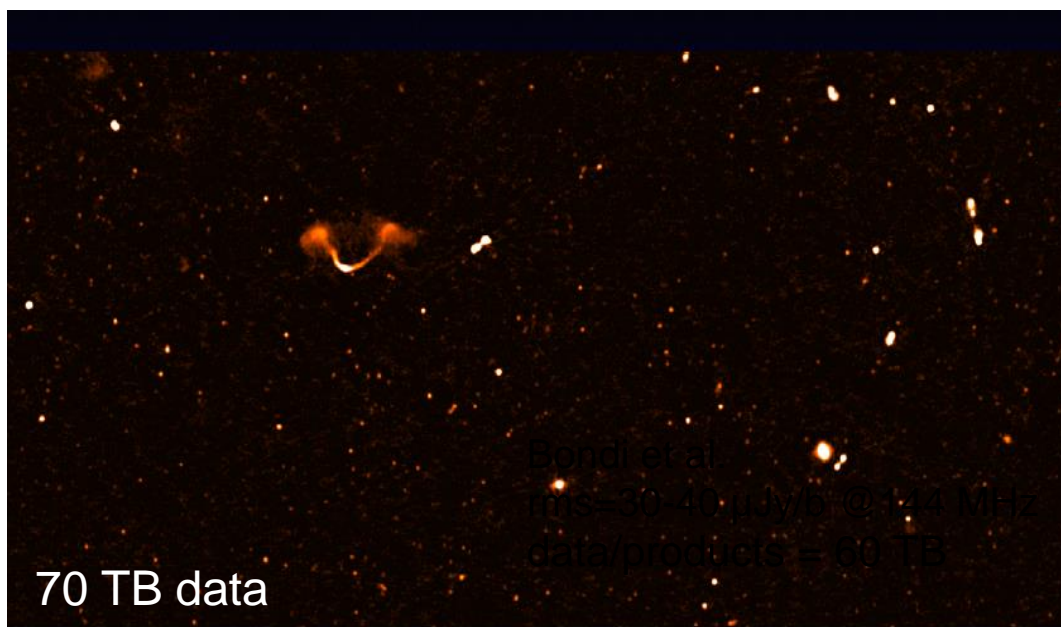
Euclid Deep Field North (EDFN)

10 square degrees circular field
r = 1.78 deg.

Equatorial:	269.73	+66.02
Ecliptic:	258.69	+89.45
Galactic:	95.76	+29.92



Dust map: Planck Collaboration, A&A, 2014, 571, 11
WISE 12cm: Mennert&Finkbeiner, ApJ, 2014, 781, 5



70 TB data

Bondi, M, Scaramella, R. et al



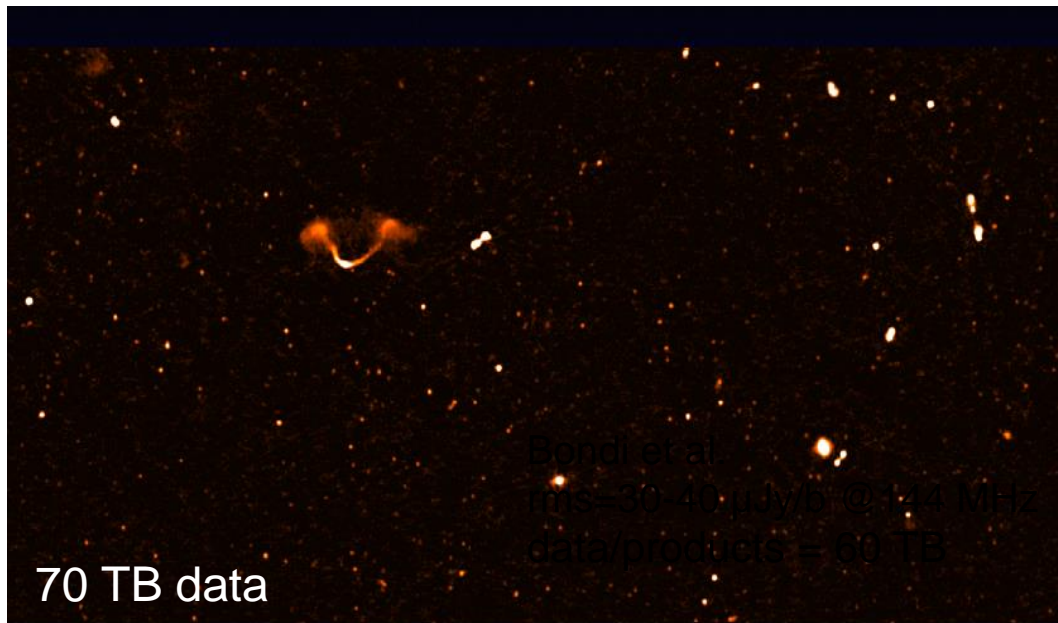
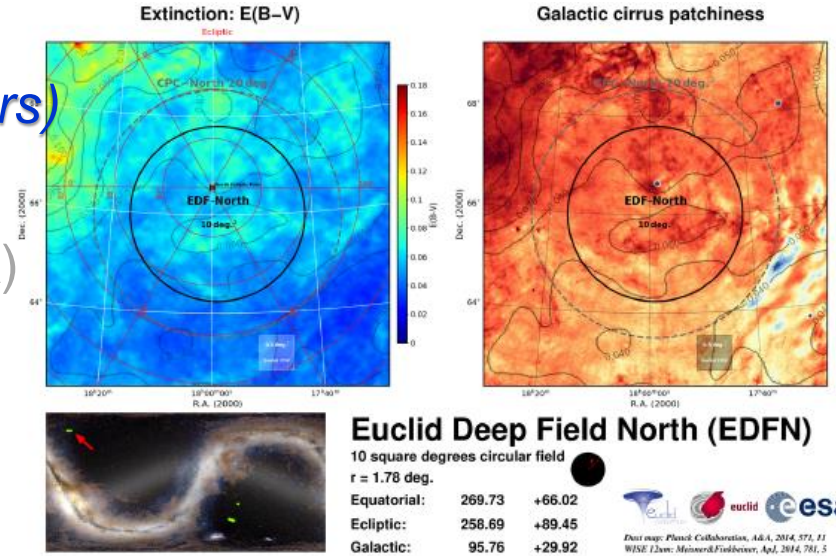
75 hrs HBA,
led R.Scaramella



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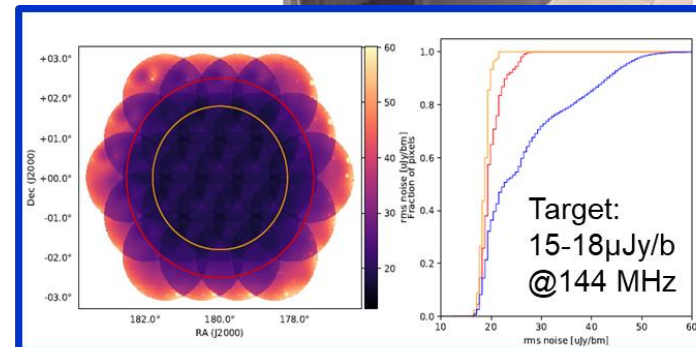


70 TB data

Bondi, M, Scaramella, R. et al



75 hrs HBA,
led R. Scaramella

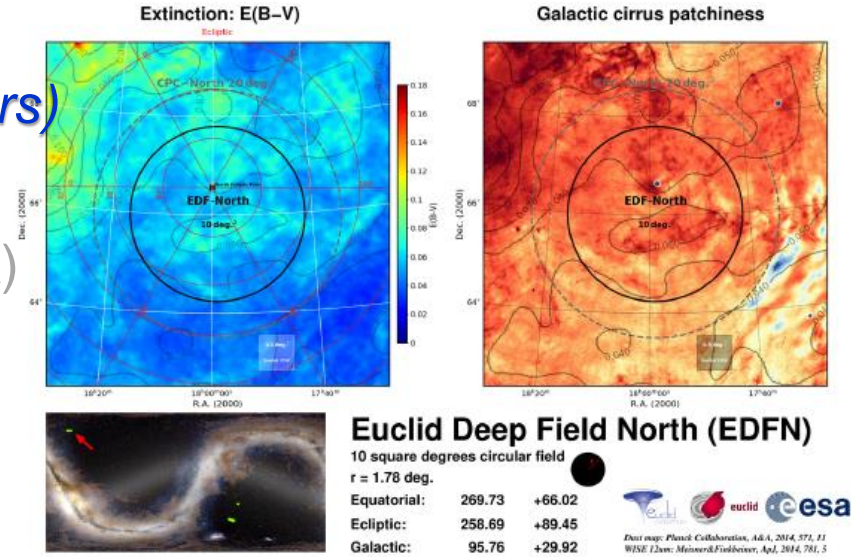


Additional 250 hrs awarded in 2022+

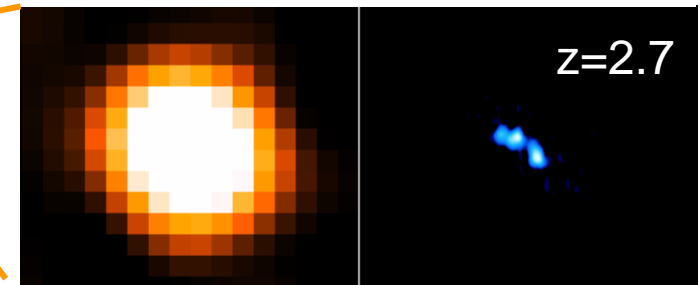
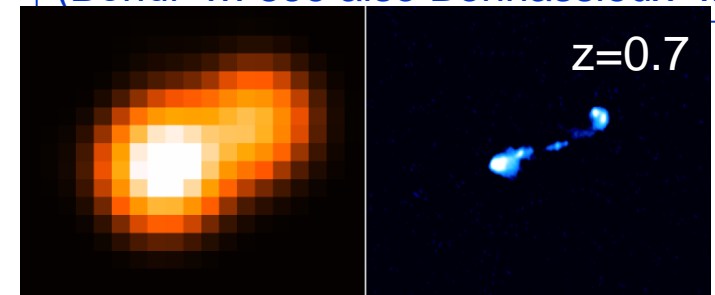
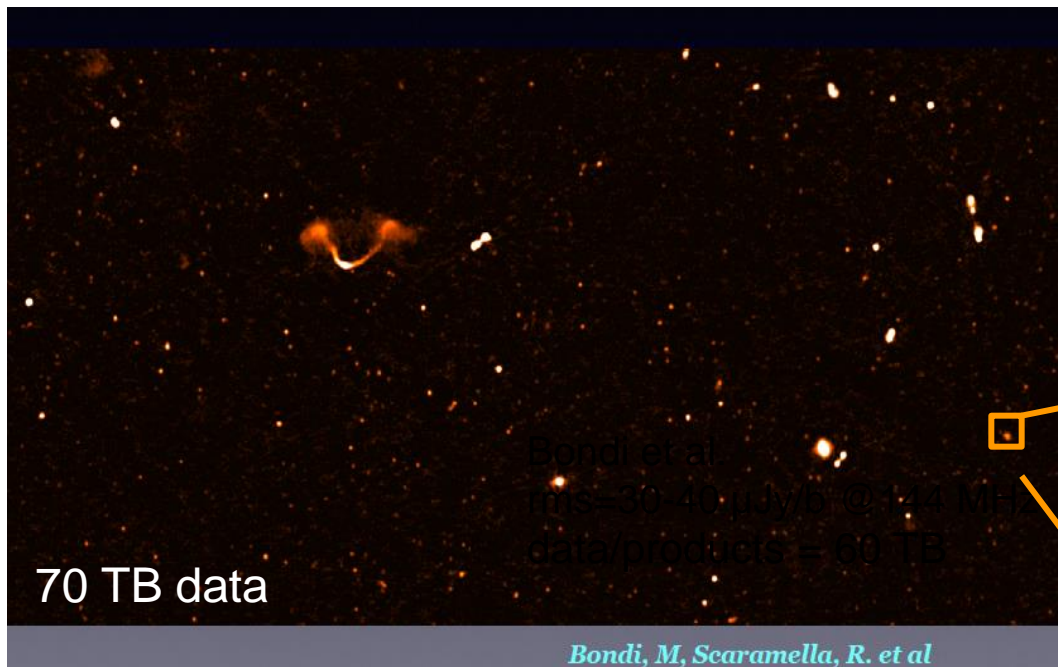
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 - WEAVE-LOFAR
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First attempts fo **LOFAR-VLBI**
(Bondi+... see also Bonnassieux+..)



LEADERSHIP & IMPACT ON IT SCIENCE

SurveyKP : *over-represented (21 TI members)*

- 2 members in the KP Board
- Leading **2/12 SWG** (galaxy clusters, LBA)
- PIship of **LoLSS** (1/2 Tier 1 surveys)
- **Synergies** :
 - WEAVE-LOFAR
 - eROSITA
 - EUCLID: PIship of EDFN (1/4 deep fields)

MagnetismKP :

- 2 members in the KP Board
- Leading **1/6 SWG** (cosmic filaments)
- **PI of the GOODS-N deep field (V.Vacca)**
250+ hrs in coll with SurveyKP

(200 TB data/products expected)



GROWTH OF THE IT COMMUNITY

- indicators: OBSERVING TIME & PUBLICATIONS-

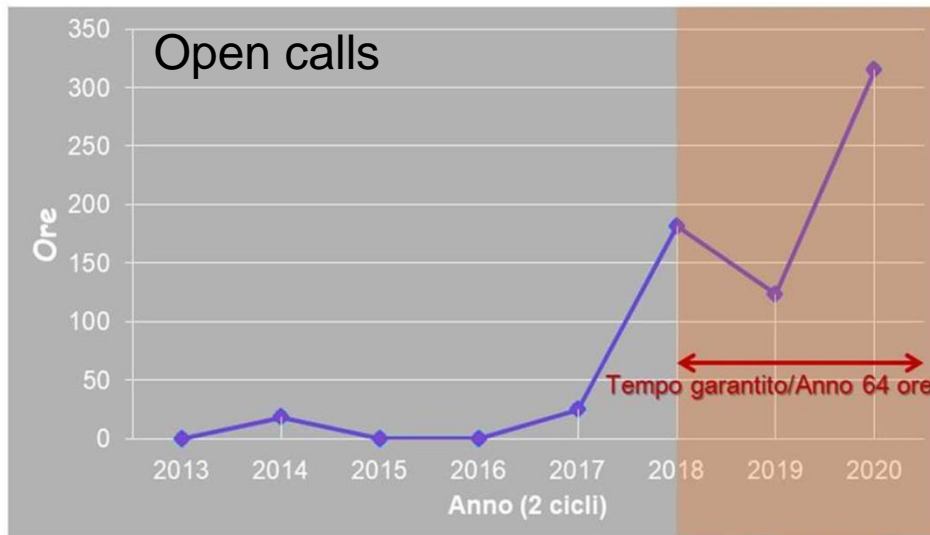
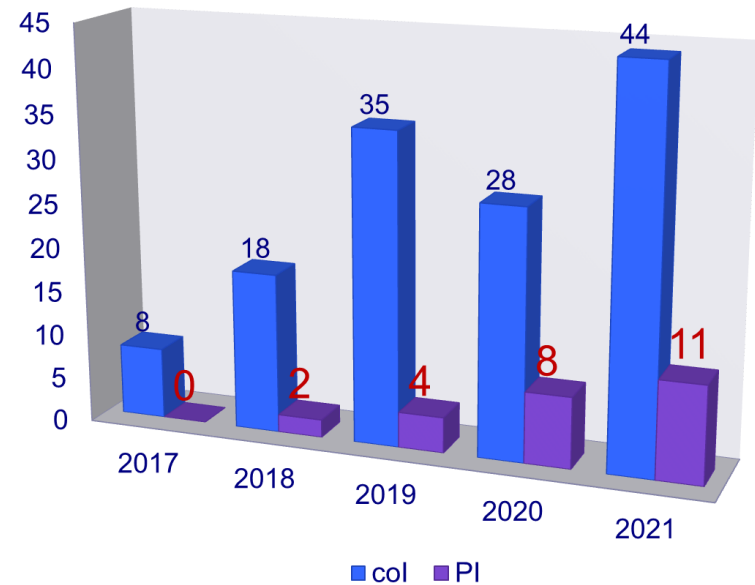


FIGURE 4: observing hrs (GO call) obtained by INAF PIs

PAPERS with KPs data/pipelines (IT researchers)



LOFAR-It refereed papers published with SKPs (35-45 papers/yr 2021+)

PHYSICAL SCIENCES

Gentle reenergization of electrons in merging galaxy clusters

Francesco de Gasperin,^{1,2*} Huib T. Intema,¹ Timothy W. Shimwell,¹ Gianfranco Brunetti,³ Marcus Brüggen,² Torsten A. Enßlin,⁴ Reinout J. van Weeren,^{1,5} Annalisa Bonafede,^{2,3} Huub J. A. Röttgering¹

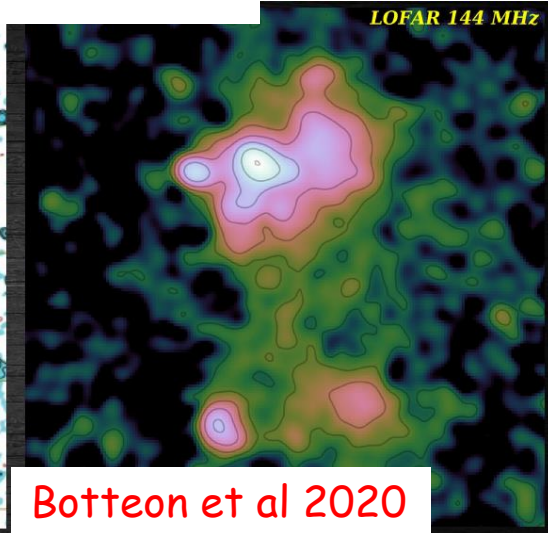
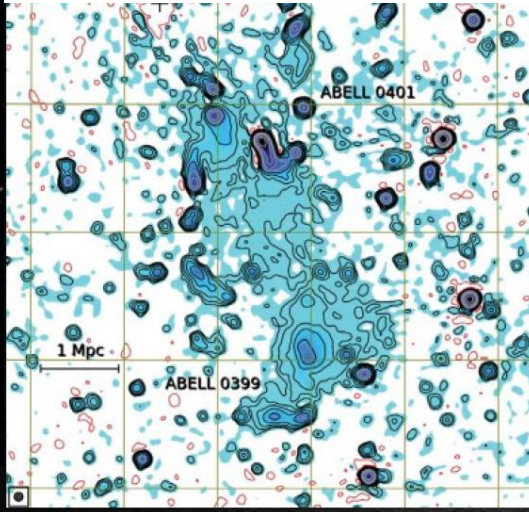


RESEARCH

RADIO ASTRONOMY

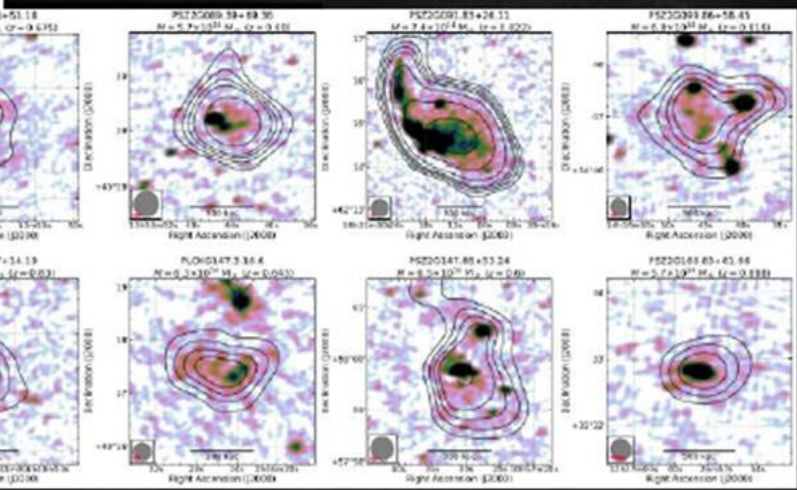
Govoni et al 2019

A radio ridge connecting two galaxy clusters in a filament of the cosmic web



Botteon et al 2020

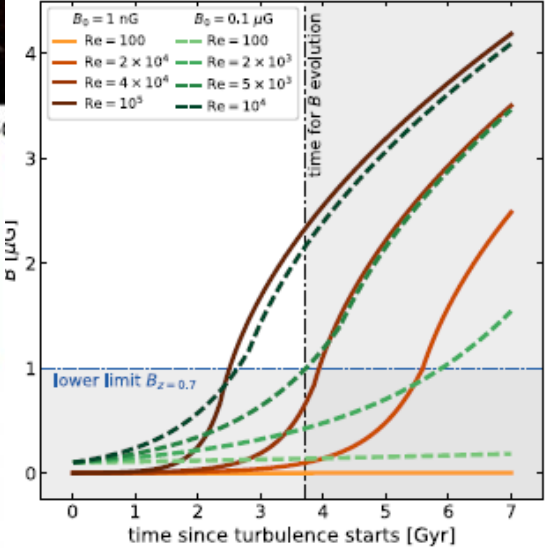
High-z radio halos (z>0.6)



Di Gennaro, van Weeren, GB, + 2020

Fast magnetic field amplification in distant galaxy clusters

nature astronomy



PHYSICAL SCIENCES

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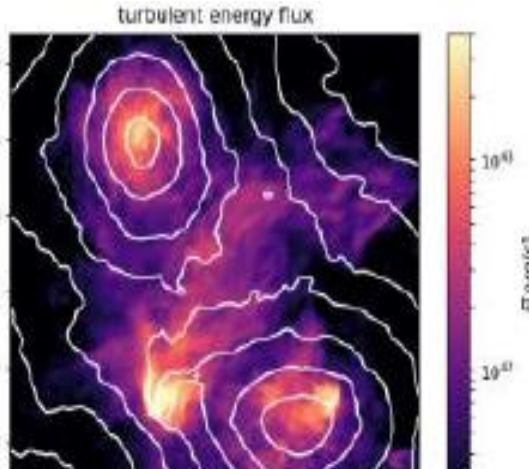
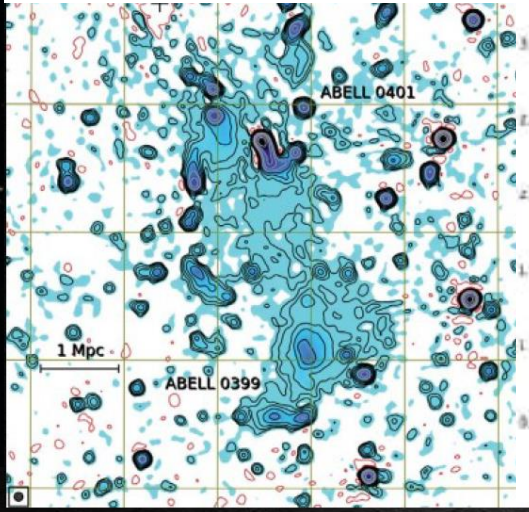


RESEARCH

RADIO ASTRONOMY

Govoni et al 2019

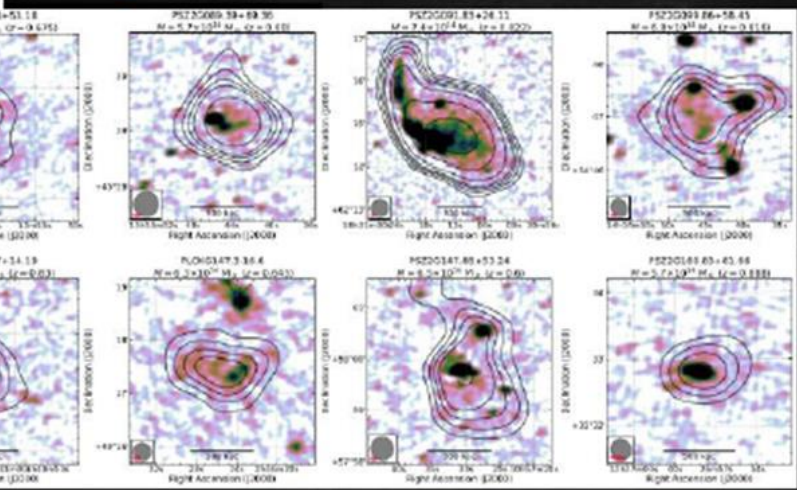
A radio ridge connecting two galaxy clusters in a filament of the cosmic web



Brunetti+Vazza 2020 PRL



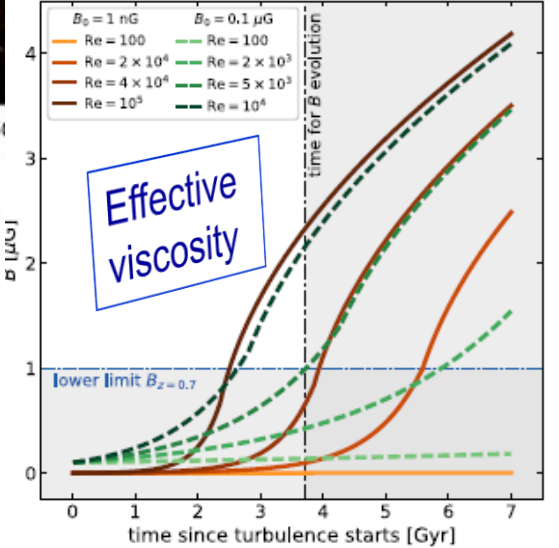
High-z radio halos (z>0.6)



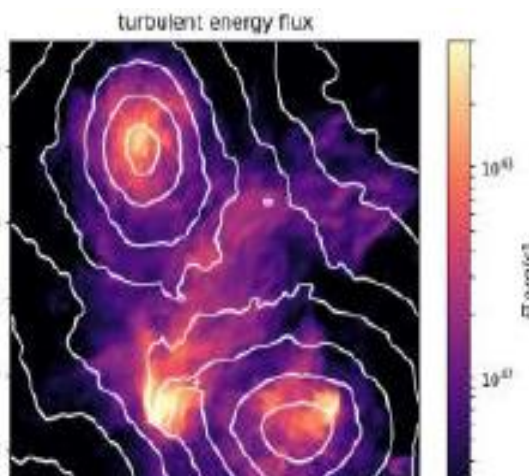
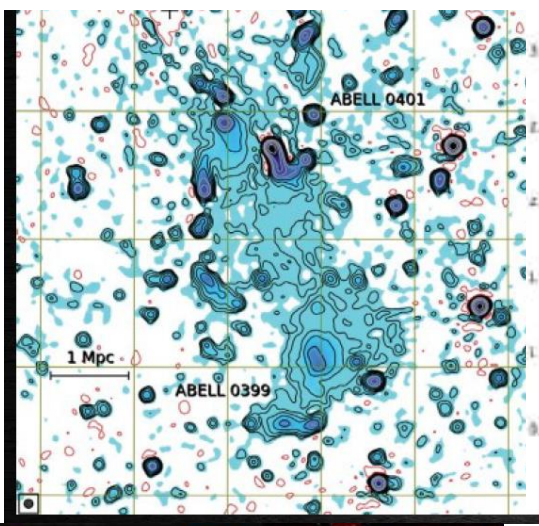
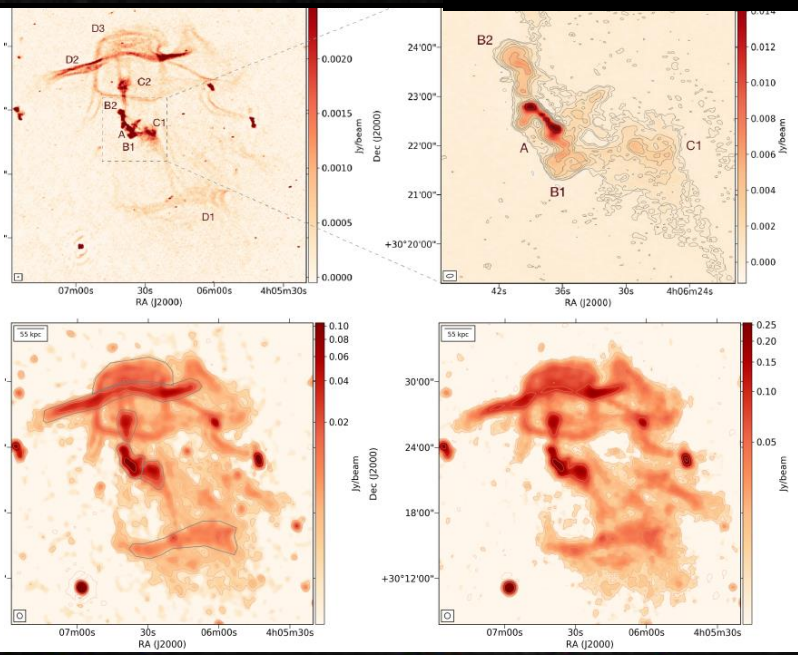
Di Gennaro, van Weeren, GB, + 2020

Fast magnetic field amplification in distant galaxy clusters

nature astronomy

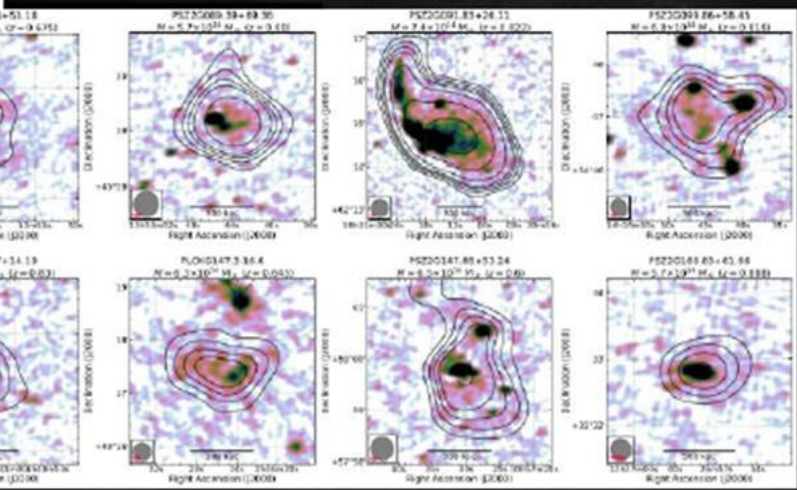


A radio ridge connecting two galaxy clusters in a filament of the cosmic web



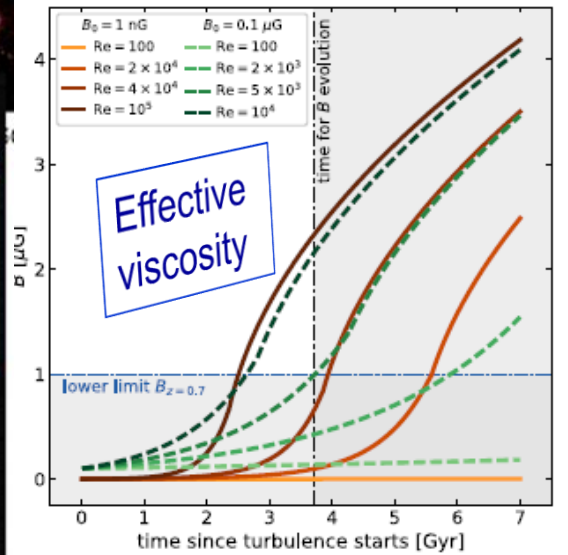
Brunetti+Vazza 2020 PRL

High-z radio halos (z>0.6)



Di Gennaro, van Weeren, GB, + 2020

Fast magnetic field amplification in distant galaxy clusters

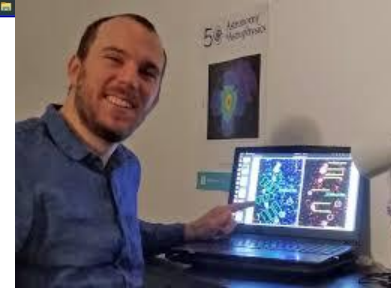




Press , PR media

Articoli relativi a LOFAR

1. Tutti i colori di un fast radio burst [31/08/2021]
2. Risoluzione record con le 70mila antenne di LoFar [17/08/2021]
3. 900 "occhi" in fibra ottica per studiare l'universo [12/07/2021]
4. La galassia che scodinzola [20/05/2021]
5. Frequenza record per i lampi radio veloci [20/04/2021]
6. Migliaia di baby stelle scoperte con LoFar [07/04/2021]
7. La storia delle galassie scritta nei getti radio [19/03/2021]
8. Venticinquemila buchi neri supermassicci per LoFar [19/02/2021]
9. Scoperto da eRosita il colosso dell'Idra [30/12/2020]
10. Il primo esopianeta da ascoltare in radio [17/12/2020]
11. Elegast, la prima nana bruna scoperta nel radio [12/11/2020]
12. Scontri galattici super magnetici all'alba del cosmo [02/11/2020]
13. Lo splendido caos di Abell 2255 [25/06/2020]
14. Lampo radio da record per Srt [22/06/2020]
15. Un Cornetto di elettroni nell'ammasso Abell 2249 [24/06/2020]
16. Aiutaci a scoprire i buchi neri supermassicci [26/02/2020]
17. Aurore extrasolari in onde radio [17/02/2020]
18. Ammassi galattici, il segreto è la turbolenza [24/01/2020]
19. Aurora cosmica tra due ammassi di galassie [06/06/2019]
20. Se il quasar ha i bassi un po' attenuati [18/03/2019]
21. Galassie mai viste nella nuova mappa di LoFar [19/02/2019]
22. Quel bradipo di una pulsar [23/10/2018]
23. L'Italia fa ancor più grande LoFar [16/04/2018]



And it is very important because it is telling us that there are other mechanisms that we didn't know before.



SCIENCE : FUTURE DIRECTIONS

PRECURSOR

Investment in LOFAR: primarily to play with science and technology with the largest SKA pathfinder at the low frequencies. Prepare the community for the SKA era.

LONG LIVING

LOFAR will remain a unique instrument at low frequencies, thanks to the **long baselines** (1000 km : 20 times longer than SKA_low).



IT funding Member

LOFAR will remain the only large interferometer sensitive to **very low frequencies** (20-60 MHz): LOFAR 2 upgrade (2021-2024) will improve performances in the LBA band.

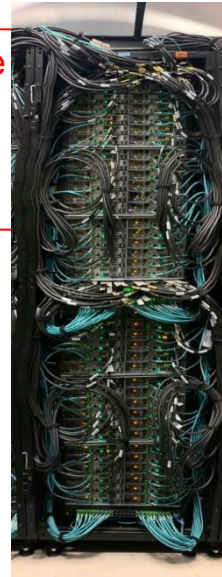
1. LBA : 2021+ : **strategic** for LOFAR 2.0

2. LOFAR VLBI : 2022+ : **new window**

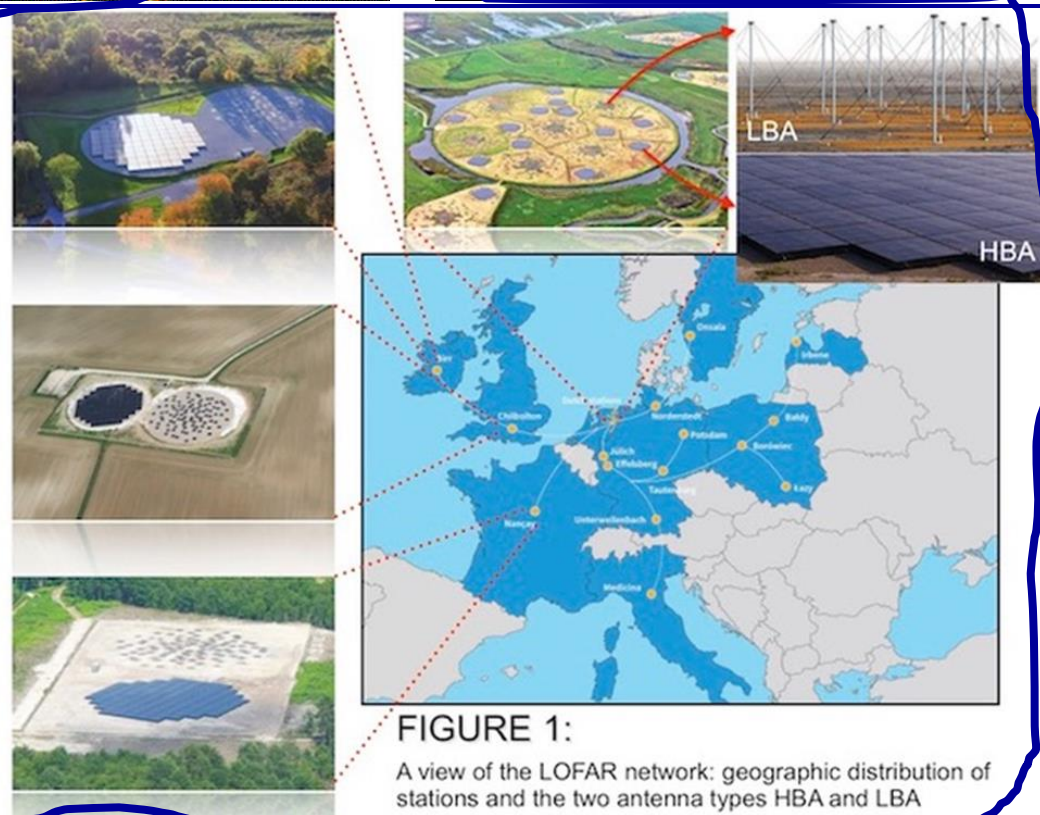
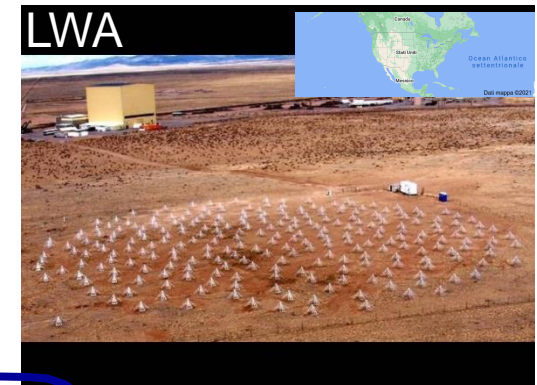
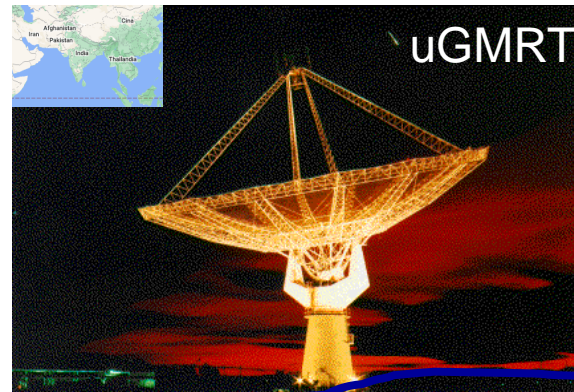
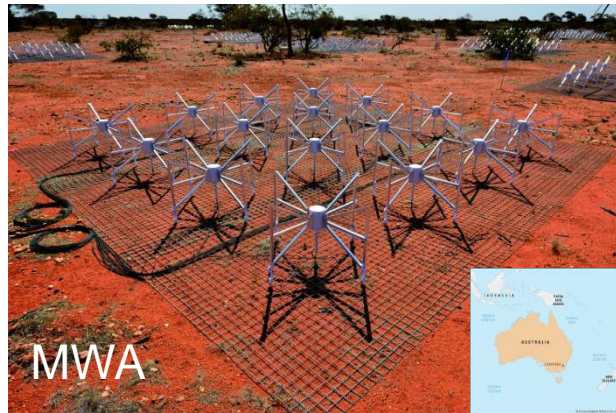
3. LOFAR 2.0 : 2024+ : new science KPs

4. SKA-LOW : 2030+ : LOFAR can drive computing/storage efforts and investments toward the SKA RC

Mapping at high resolution one LOFAR pointing requires 300,000 core hrs. **LOFAR is pushing radioA into HPC**



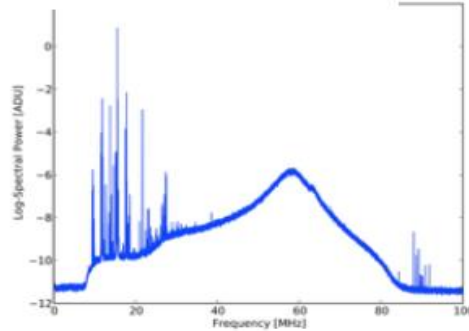
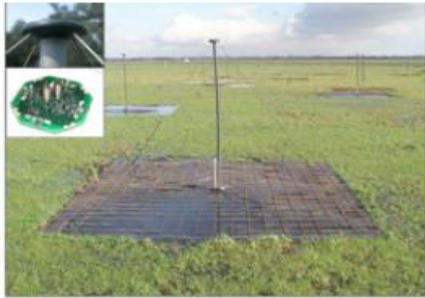
The family of SKA-low precursors & pathfinders



THE LOW FREQUENCY ARray

Giant digital aperture array radio telescope opening up a new window in the electromagnetic spectrum at low radio frequencies

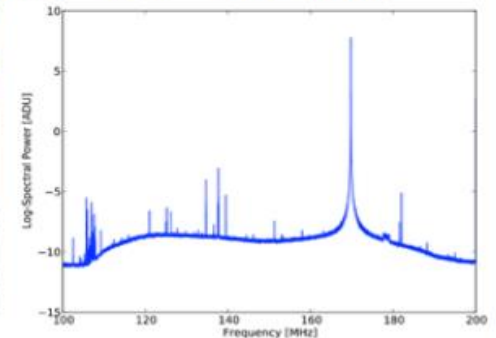
Low- Band Antennas 10-90 MHz



(van Haarlem + 2013)



High- Band Antennas 120 - 200 MHz

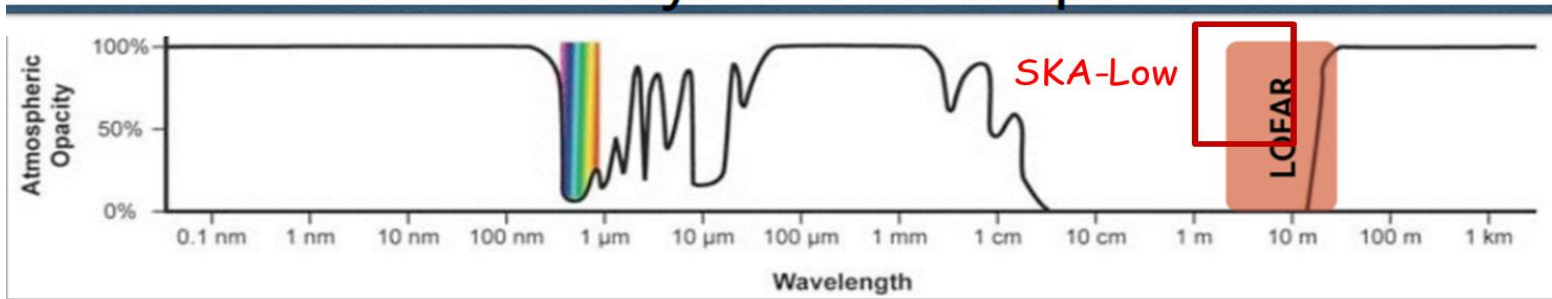


THE LOW FREQUENCY ARray

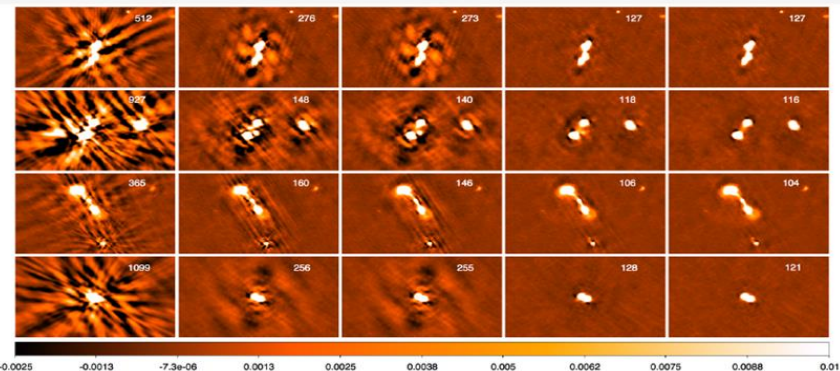
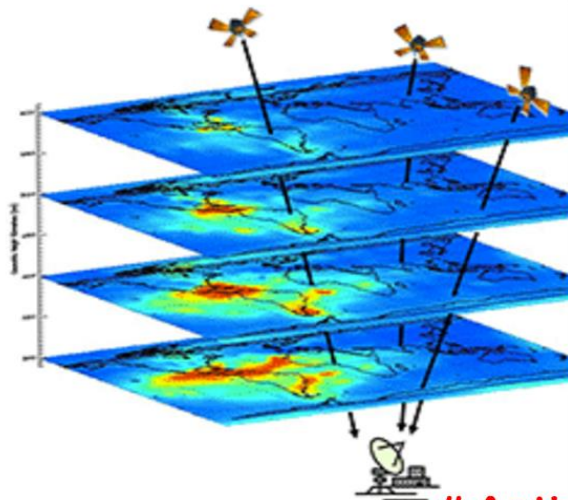
Giant digital aperture array radio telescope opening up a new window in the electromagnetic spectrum at low radio frequencies
- The largest (area & dataflow) pathfinder toward the SKA(low) -

BIG Challenges with data calibration and analysis

Our enemy: the ionosphere



Facet calibration

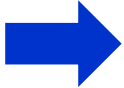


Demonstrating direction dependent calibration (van Weeren R. J., et al., 2016, ApJS, 223, 2)

Anticipate the challenges with the SKA LOW

MIUR

ILEC



2022/23

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INAF PRESIDENT

INAF DS

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RESERVED TIME

SKPs

OPEN TIME

LOFAR KEY SCIENCE PROJECTS

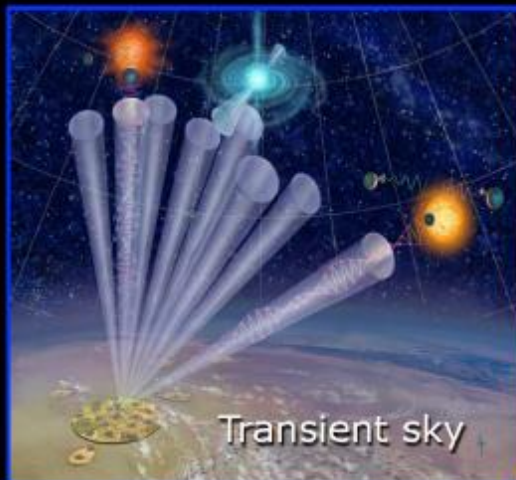
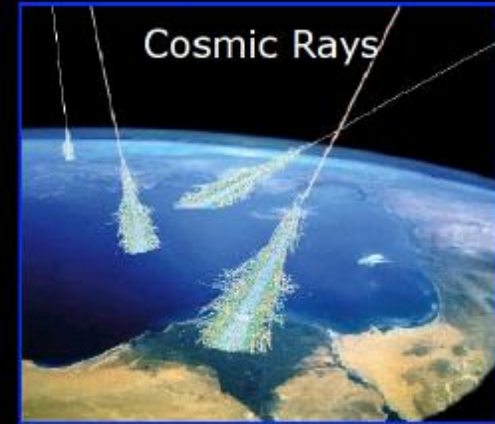
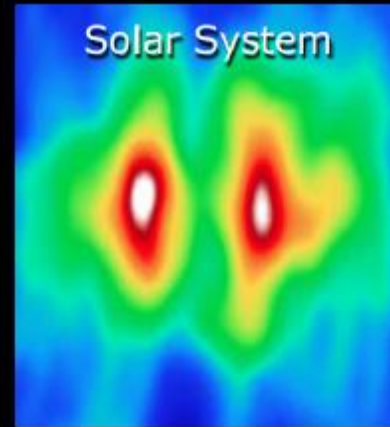
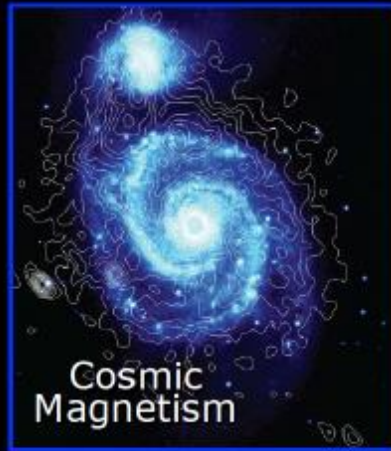
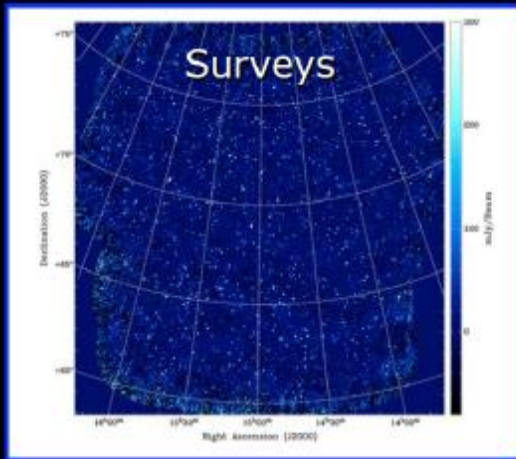
The most impactful scientific activity and technical solutions are developed within these communities

1

4

5

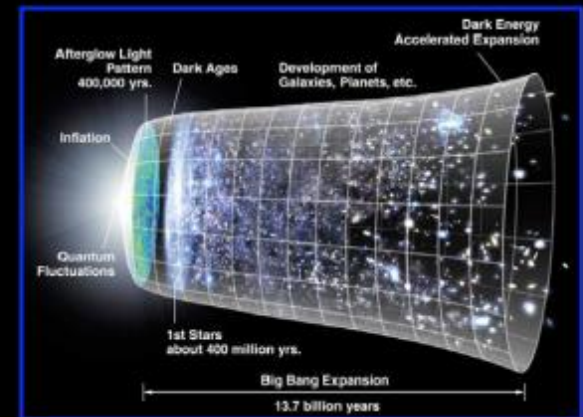
6



3



2



Epoch of Reionization

INVOLVEMENT IN SKPs

Involvement in Science KPs is based on balance of Member return-on-investment

- IT investment is (only) about 1/50 of the ILT.
- IT science community is much bigger/active than several other communities from Member countries with larger investment
- IT science community has potential to activate synergies with other large facilities

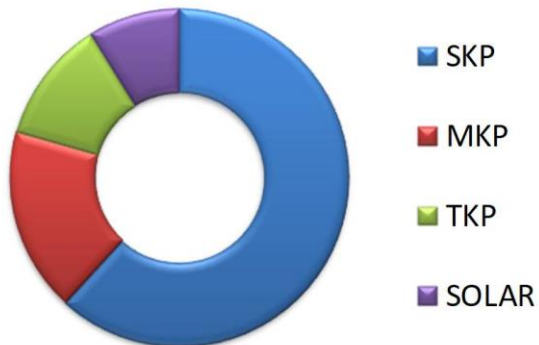
1. Call for Interest :

- July 2018
- Feb 2019

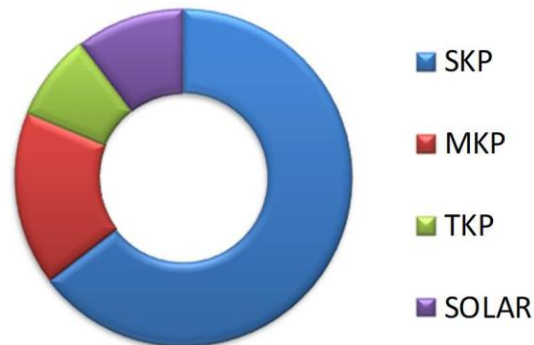
LOFAR-It Board mediated between applicants and KPs management

2. Sporadic requests from researchers to the KPs management

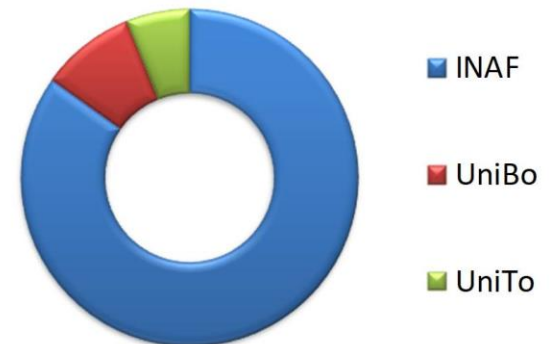
TI MEMBERS (32)



TOT (TI+TD) MEMBERS (45)



TI MEMBERS (32)



LOFAR KEY SCIENCE PROJECTS

The most impactful scientific activity and technical solutions are developed within these communities

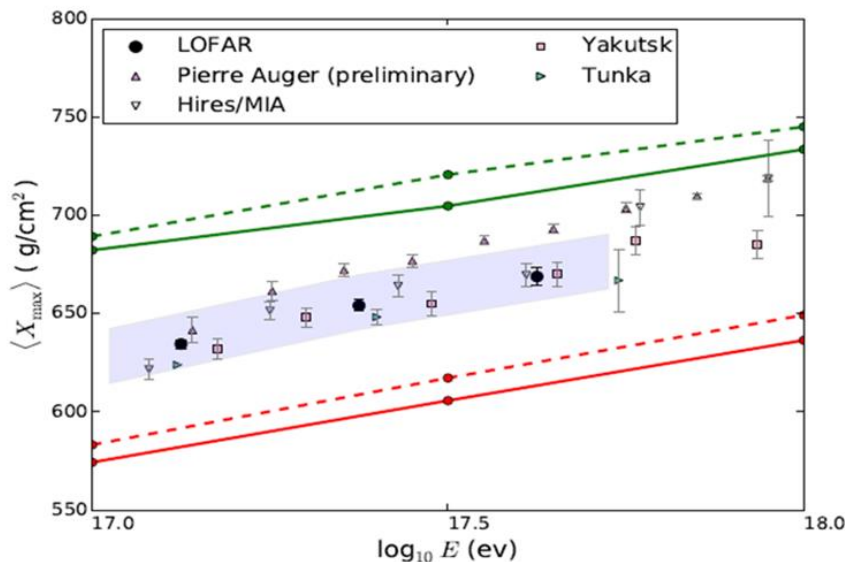
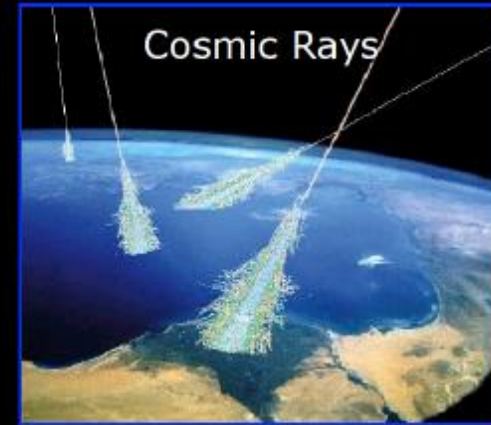
LETTER

doi:10.1038/nature16976

6

A large light-mass component of cosmic rays at 10^{17} – $10^{17.5}$ electronvolts from radio observations

S. Buitink^{1,2}, A. Corstanje³, H. Falcke^{2,3,4,5}, J. R. Hörandel^{2,4}, T. Huege⁶, A. Nelles⁷, J. P. Rachen⁸, L. Rossetto⁹, P. Schellart², O. Scholten^{1,5}, S. ter Veen³, S. Thoudam³, T. N. G. Trinh⁶, I. Anderson¹⁰, A. Asgekar^{1,11}, I. M. Avruch^{12,13}, M. E. Bell¹⁴, M. J. Bentum^{1,15}, G. Bernardi^{16,17}, P. Best¹⁸, A. Bonafede¹⁹, F. Breitling²⁰, J. W. Broderick²¹, W. N. Brown^{1,13}, M. Brüggen¹⁹, H. R. Butcher²², D. Carbone²³, B. Ciardi²⁴, J. E. Conway²⁵, F. de Gasperin¹⁹, E. de Geus^{1,26}, A. Deller³, R.-J. Dettmar²⁷, G. van Diepen³, S. Duscha³, J. Eisköffel²⁸, D. Engels²⁹, J. E. Enriquez³⁰, R. A. Fallows³¹, R. Fender³², C. Ferrari¹⁹, W. Frieswijk³, M. A. Garrett^{1,32}, J. M. Grieblmeier^{33,34}, A. W. Gunst³⁵, M. P. van Haarlem³, T. E. Hassall³⁶, G. Heald^{1,13}, J. W. T. Hessels^{1,37}, M. Hoefler¹⁹, A. Hornegger³, M. Isacbelli³⁸, H. Instecca^{32,39}, E. Juette²⁷, A. Karastergiou³⁰, V. I. Kondratiev^{3,30}, M. Kramer³, M. Kuniyoshi¹⁹, G. Kuper³, J. van Leeuwen^{1,23}, G. M. Loose³, P. Maat³, G. Mann³⁰, S. Markoff^{3,30}, R. McFadden³, D. McKay-Bukowski^{39,40}, J. P. McKean^{1,42}, M. Mevius^{1,33}, D. D. Mulcahy³⁸, H. Munk³, M. J. Norden³, E. Orrù³, H. Paas⁴⁴, M. Pandey-Pommier⁴², V. N. Pandey³, M. Pietka³⁰, R. Pizzo³, A. G. Polatidis³, W. Reich³, H. J. A. Röttgering³⁵, A. M. M. Scaife³¹, D. J. Schwarz⁴³, M. Serylak³⁰, J. Shuman³, O. Smirnov^{27,44}, B. W. Stappers³⁰, M. Steinmetz³⁰, A. Stewart³⁰, J. Swinbank^{1,3,45}, M. Tagger³¹, Y. Tang³, C. Tasse^{44,46}, M. C. Toribio^{1,22}, R. Vermeulen³, C. Vocks³⁰, C. Vogt³, R. J. van Weeren¹⁶, R. A. M. J. Wijers²³, S. J. Wijnholds³, M. W. Wise^{1,23}, O. Wucknitz³, S. Yatawatta³, P. Zarka⁶ & J. A. Zensus³



LOFAR KEY SCIENCE PROJECTS

The most impactful scientific activity and technical solutions are developed within these communities

Article

Chromatic periodic activity down to 120 megahertz in a fast radio burst

<https://doi.org/10.1038/s41586-021-03724-8>

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Inés Pastor-Marazuela^{1,2}, Liam Connor^{1,2,3}, Joeri van Leeuwen^{1,2,3}, Yogesh Maan², Sander ter Veen², Anna Bilous², Leon Oostrum^{1,2,4}, Emily Petroff¹, Samayra Straal^{1,4}, Dany Vohi¹, Itsk Attama⁴, Olivier M. Boersma^{1,2}, Eric Koolstra², Daniel van der Schuur², Alessio Sclocco⁴, Roy Smits², Elizabeth A. K. Adams^{2,5}, Björn Adobahr⁴, W. J. G. de Blok^{2,3,6}, Arthur H. W. M. Coolen², Steds Damstra², Helga Dönes², Kellay M. Hess^{2,7}, Thijs van der Hulst², Boudewijn Hut², V. Marianna Ivashina⁸, Alexander Kutkin¹⁰, G. Marcel Loose², Danielle M. Lucero^{2,9}, Agnes Mikz², Vanessa A. Moss^{2,11,12}, Hank Mulder¹, Menno J. Norden², Tom Oosterloo^{2,3}, Emanuela Orrù², Mark Rutter² & Stefan J. Wijnholds²

Nature



3



THE ASTRONOMICAL JOURNAL LETTERS, 94(6), 19 (pp), 2017 September 10
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<https://doi.org/10.3847/2041-8213/aa6307>



A Millisecond Pulsar Discovery in a Survey of Unidentified *Fermi* γ -Ray Sources with LOFAR

Z. Pleunis^{1,2}, C. G. Bassa³, J. W. T. Hessels^{2,3}, V. I. Kondratiev^{3,4}, F. Camilo⁵, I. Cognard^{6,7}, J.-M. Grieblmeier^{4,7}, B. W. Steppers¹, A. S. van Amerongen¹, and S. Sanidas²

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